

# About Flying Fishes

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IT has recently been the good fortune of the writers to study an exceptionally interesting collection of flying fishes brought back by the "Arcturus" expedition of 1925, under the direction of Mr. William Beebe. A report on this collection will shortly appear in *Zoologica*, the technical series of the New York Zoological Society. Meanwhile, the readers of NATURAL HISTORY will, we think, be interested in various facts and problems concerning flying fishes.

The ability to indulge in more or less protracted aerial excursions is known to have arisen independently in four present-day groups of fishes, and in at least one fossil group. These groups are:

THE AFRICAN FRESH-WATER FLYING FISH (*Pantodon*), a small species related to the herring-trout group.

THE SOUTH AMERICAN FRESH-WATER FLYING FISH (*Gasteropelecus* and related genera), belonging to the tropical family *Characidae*, which is related to catfishes and minnows.

A FOSSIL HAPLOMID (*Chirothrix*), related to our pikes and pickerels.

TRUE FLYING FISHES (*Exocoetidae*) a large marine family, all the members of which have powers of flight. They are related to the slender halfbeaks, billfishes, etc.

THE FLYING GURNARD (*Dactylopterus*) one of the mail-cheeked fishes, related to the sea-robins and sculpins.

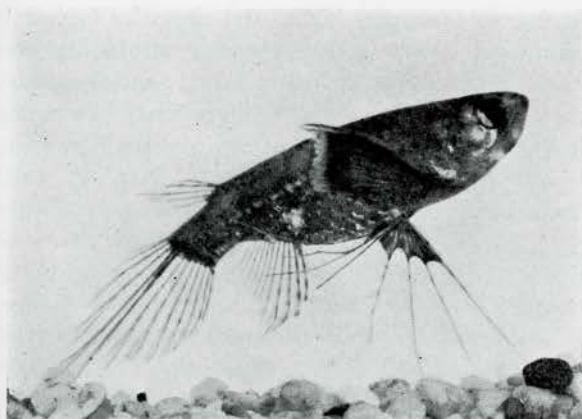
Thus we see that several unrelated groups of fishes have developed independently the ability to fly. However, the true flying fishes (*Exocoetidae*) characteristic of the trade-wind belts of open, tropical oceans, excel all others in aerial powers, and furthermore, we

have here a large and varied group of aviators, not merely one or a few related species with powers of flight. It is also of interest that the flying gurnard is the only member of the great modern group of spiny-rayed fishes (*Acanthopterygii*) to have developed the fin equipment necessary to support it for even a short distance in the air. Its close relatives are bottom-dwelling fishes which lunge upward into the free water above them, and then coast down again to the bottom, with fins set. The flying gurnard's flight is somewhat analogous to this habit, the difference being that the fish leaps into the air, where its relatively large breast fins are able to support it for a short journey.

Aside from the flying gurnard, the other four groups of flyers are all less modern fishes of more primitive organization, perhaps more closely related to each other than any are to the flying gurnard.

Of the fossil *Chirothrix* we naturally know little. In this form it was the ventral fins which were most enlarged, placed anteriorly, close to the pectorals. Though it is not universally admitted that the fish was a flyer, such is the most reasonable hypothesis advanced to explain its fin development.<sup>1</sup> Of the African and South American fresh-water flying fishes, the former, *Pantodon*, sometimes kept in balanced aquaria, has very slight powers of flight. The South American *Gasteropelecus* is a relatively better flyer, especially con

<sup>1</sup>Landois, 1894, *Neues Jahrbuch Mineralogie*, Stuttgart, II, p. 228-235.



The African fresh-water "flying-fish" *Pantodon*, from a photograph by Dr. E. Bade

sidering its small size. It is said that it flaps its pectoral fins vigorously during passage through the air. The structure and muscles of this interesting form are described in detail in the *Annals and Magazine of Natural History* for 1913.<sup>1</sup>

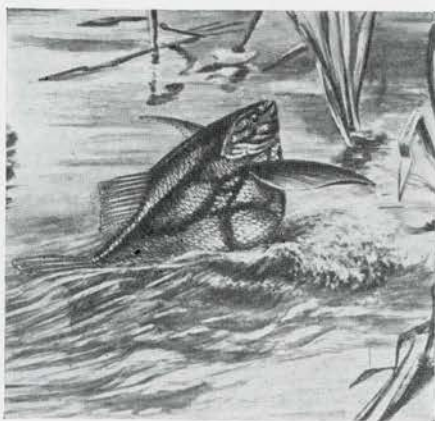
With this short résumé, we will turn to a more detailed discussion of the true marine flying fishes familiar to all who venture on blue water. Their abundance and world-wide distribution bespeak the success which has come to them by invasion of that realm for the most part held (among back-boned animals) by birds.

The first question which comes to mind is "Why do flying fishes fly?" Undoubtedly the chief use of flight to these fishes is that thereby they escape predaceous enemies. The rapid approach of a submerged body, such as the hull of a ship, will cause them to rise into the air and soar for several hundred yards or more. The larger species fly singly, the smaller ones frequently leave the water in a glistening silver "flock" or "shoal," and they may soar for several hundred yards or more before dropping back into their

native element. To pursuing enemies, for whom the surface of the water is virtually a ceiling to be avoided, this ability on the part of their prey must be a source of considerable and frequent disappointment.

By "banking" to right and to left, flying fish can alter the direction of their course. In the daytime they are able to see where they are going, and seldom fall aboard ship. At night

not being able to see, they frequently strike against the rigging and fall to the deck. The dolphin (*Coryphæna*), perhaps the swiftest fish that swims the open sea, feeds largely on flying fishes. It frequently thrusts its head and shoulders clear of the water to seize them, and will follow under water the curving shadow of a fish above with astonishing speed, ready to seize it when it descends. At the same time it is probable that most of the individuals captured by the dolphin are those which by some mischance are slow in gaining the air, or which do not



The South American fresh-water flying fish, *Gasteropelecus*, from a drawing by Dr. E. Bade

<sup>1</sup>Ridgewood, 1913, *Annals and Magazine of Natural History*, (8) XII, pl. 544-548, pl. XVI.



make a perfect flight. Flying fish fly much more frequently in a fresh breeze than when it is calm and in light air. Under optimum conditions they seem to do so from exuberance as well as for refuge.

A second natural question would be, "How do flying fishes fly?" This introduces a problem that has bothered naturalists, aeronautical engineers, philosophers, and others for a long time. There is today anything but unanimity of opinion on this subject. The argument as to whether these fishes sustain their flight by motion (flapping) of the wings or merely soar as gliders, has not been satisfactorily settled. There is some truth in both points of view. The flight is largely a planing one, but at certain times and under certain conditions a definite wing motion may enter in and contribute to it. The enlarged pectoral fins or "wings" are, on anatomical grounds and structurally—from an engineering point of view—ideal gliding planes, so arranged as to be easily held rigid at the proper angle. R. E. Dowd<sup>1</sup> has worked out the structure of the flying fish wing from an aeronautical point of view, and arrived at the conclusion that it is extremely well "designed" for planing, but not for a flapping flight.

The wings of large flying fishes are sometimes seen to vibrate or flutter, a motion more reasonably referable to tension in setting them, or to the wind, than to a definite function in flight. In very small and young fishes, on the other hand, the wings vibrate to such an extent that they blur, like those of a flying insect. It seems that with an increase in age and size, a buzzing beelike flight is replaced by a true

soaring flight, and that the former is very likely a function of absolute size as are so many larval specializations. Flying fishes fly more freely in a strong breeze, and attain greater elevation, speed, and distance than in calm weather. The conclusion is almost inevitable that they utilize the wind to some extent to lift and propel them, even though it is difficult to understand how this would be accomplished.

A detailed description of the flight of one of the larger flying fishes may be quoted from C. L. Hubbs (1918, *Copeia*, No. 62, p. 85–88) as follows:

The details of the flight of *Cypselurus californicus*, never described with sufficient fullness, may readily be observed by a person at the bow of a small vessel plying through the sea off the coast of southern California, during the summer months. Seemingly indifferent to the direction of the wind, and without apparent unison in their flight, these flying fishes scatter before the boat, as Dr. Jordan says, like grasshoppers before one walking in a meadow.

They appear never to leap directly into the air, as some species are said to do, but, on emerging from the water with greater or less velocity, they immediately spread their wide pectoral "wings" and move forward on the surface like tiny aeroplanes, for a distance averaging perhaps twenty-five feet. While on the water, their sole source of propulsive power appears to be the normal organ of locomotion in fishes—namely, the tail. The pectoral fins, to be sure, are seen to vibrate, but apparently with neither sufficient amplitude nor velocity to propel the fishes forward on the surface, nor to raise them from the water. The vibration of the "wings," though claimed by some to indicate true flight, seems to be due to the less evident, but still observable shaking of the whole body, which in turn is evidently caused by the rapid side-to-side sweeping of the strengthened lower lobe of the caudal fin. The greatest movement of the "wings" is toward their tips, apparently because the fin is rather flexible distally, and because the amplitude of motion is much increased so far out from the body. The moment the fishes rise into the air, their

<sup>1</sup>Dowd, R. E. 1921, The Aeronautics of the Flying Fish. *Aerial Age Weekly*, Jan. 10, pp. 464–465. 3 figs.



THE BUTTERFLY FLYING FISH

*Enlarged  $1\frac{3}{4}$  times*

Young of a "four-winged" flying fish (*Cypselurus furcatus*). Its mottled color, unlike that of the adult (see next plate) is doubtless correlated with a habit of hiding about drifting weed. It is one of those species the young of which have a double barbel on the chin. From a painting by Helen Tee-Van



A FOUR-WINGED FLYING FISH

*Slightly reduced*

An adult "four-winged" flying fish (*Cypselurus furcatus*), with ventral fins placed posteriorly and enlarged to function as secondary planes. Its color matches that of the "two-winged" species of similar habitat. It measures about six inches "over all" when full grown. From a painting by Helen Tee-Van





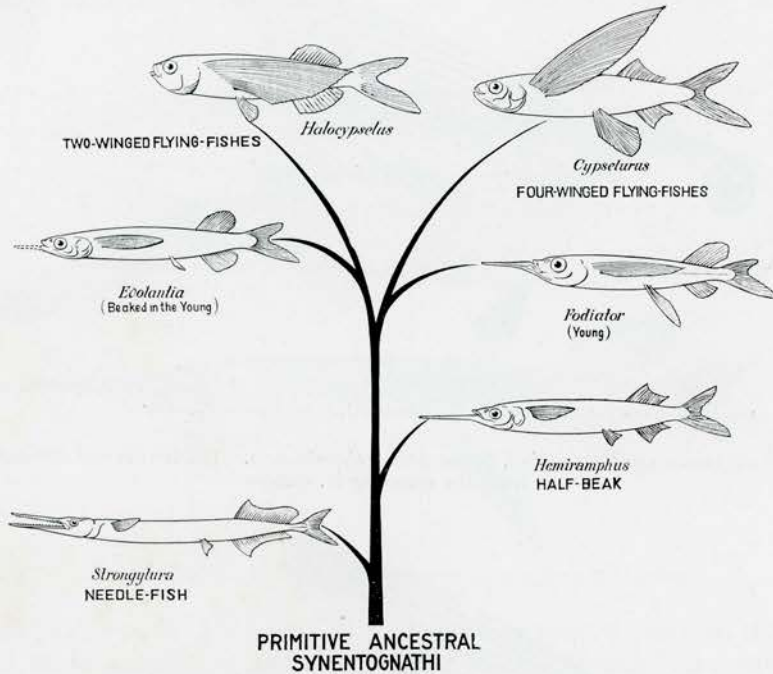
A TWO-WINGED FLYING FISH

*Slightly reduced*

One of the "two-winged" flying fishes (*Halocypselus evolans*). Its beautiful blue color matches that of the open ocean, and is characteristic of animals which float or swim unattached at the surface on "blue water." When full grown this fish attains a length of about six inches. From a painting by Helen Tee-Van

pectorals are held taut: when viewed from the rear they are seen clear-cut, like knife edges. It is very probable, therefore, that not only while on the surface, but in the air

The turning is apparently accomplished by the tail and tail fin, which are seen bent in the direction toward which the course is being altered.



Tentative family tree of the needle-fish, flying-fish group

as well, the great pectoral fins (of this species, at least) are not flapping wings, but rather planes of support.

While the flying fishes are attaining on the surface the velocity necessary to carry them soaring away through the air, the ventral fins, also enlarged in *Cypselurus*, remain close-folded against the body. Suddenly they are broadly spread, as elevating planes, and the fish gracefully rises into the air. During the flight the ventrals seem to serve an additional purpose: for, when observed from the advantageous position directly in line with the course of flight, these fins may be seen repeatedly changing their plane, sometimes independently. Apparently serving thus as stabilizing planes, they seem to keep the course of the fishes through the air rather steady, even in a gale. No such regulatory movement of the pectoral fins is apparent.

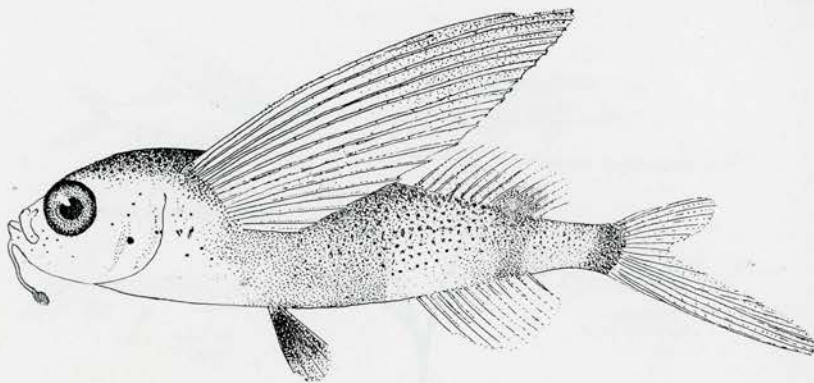
The flight of these fishes is often straight in direction, but not invariably so; when well under way it may even become semicircular.

During their flight, the fishes seldom rise higher than about five feet (though they may be farther above the trough of the swells), except when forced upward by a gust of wind. The length of the initial flight, unless following a very poor start, varies usually between fifty and three hundred feet; but when flying with the wind, distances of about a quarter mile in the air are occasionally made.

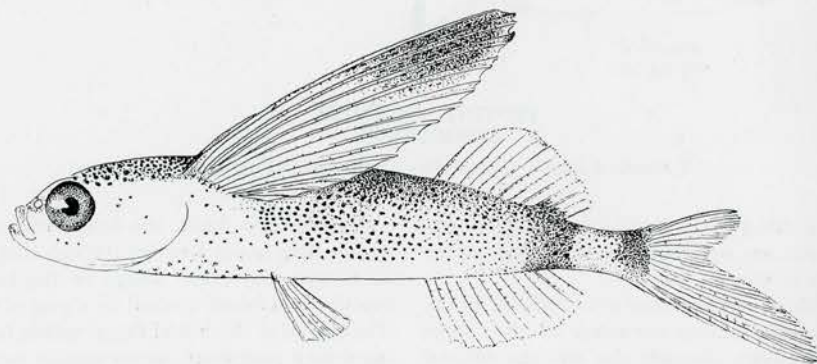
While in the air, the body appears to be arched upward, and the tail is held lower than the head. As the flight reaches its end, the force of gravity having gradually overcome the upward thrust of air pressure against the pectoral planes, the lower caudal lobe strikes the water first, and the ventral fins are folded. The fishes now either suddenly end their flight, or continue it, they being in the same position as when they first came to the surface. The second flight is a repetition of the first. The necessary velocity to propel them through the air is again attained on the surface by the rapid movement of the tail,

which begins as soon as the caudal fin touches the water. Two or three successive flights are frequently made, and occasionally four, or even five, are undertaken before the fishes

soar straight toward the side of a vessel, until they seem about to crush themselves. But they suddenly plunge into the water, twist directly backward in their course within



Young two-winged flying-fish, *Halocypselus obtusirostris*. The barbel will distinguish it from the common *H. evolans*



Young two-winged flying-fish *Halocypselus evolans*. To give the scale, a reference line of one inch accompanies this and the other figures

finally sink beneath the surface. Usually the flights are of increasingly shorter distance and duration; at the end of the last the pectoral fins, as well as the ventrals, are instantly folded, and the fishes drop into the water with a splash. They light in a horizontal position, ready for their dashing movements which are seen for a second under the surface.

Owing to the greater resistance offered by the water, changes in the direction of movement are much more swiftly accomplished in that medium than in the air. Sometimes they

a radius of about ten feet, and make away in the opposite direction, either in the water or in the air.

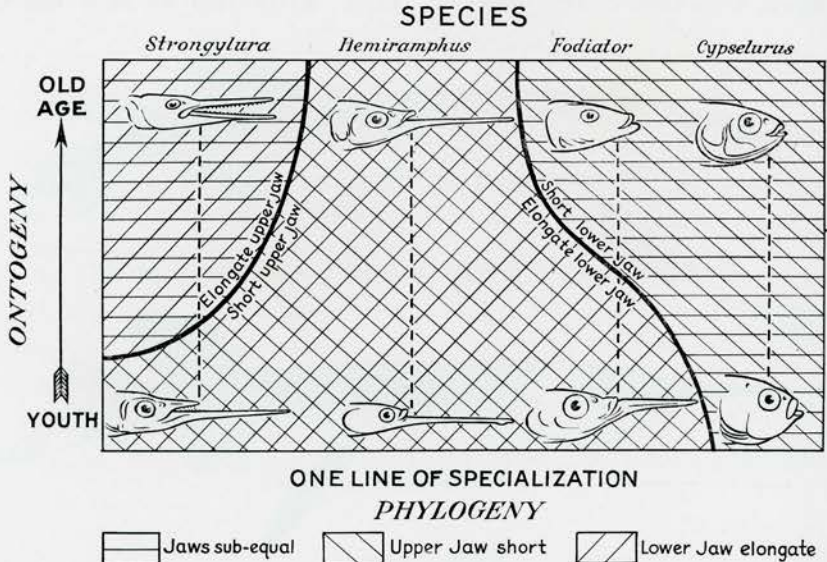
Now let us consider the relations between different flying fishes, from what manner of fish they have been developed, the trend of evolution in this group. There is little question that they are descended from some billfish-like ancestor, through the half-beaks. The billfish, or marine gar is a



fishes, (*Fodiator*), the young have a long lower jaw like that of a halfbeak, which is gradually reduced with age, until the adult has only a pointed chin.

one may fancy some homology between such barbels and the skin of the beak in *Evolantia*.

Specialized flying fishes divide them-



Evolutionary diagram showing greater duration of the half-beak character in young than in adult

In most of the species the jaws have become quite short, undoubtedly much as in some remote ancestors, even antedating the billfishes. Another primitive flying fish (*Evolantia*), with short wings, has a "half-beak" in the young which is of a different character from that of *Fodiator*. With the growth of the fish, this projection does not merely lag; seemingly the normal thing is for the skin of the beak to break away from its slender central supporting cartilage, the cartilage then breaks off, and the skin heals on to the chin. A peculiar specialized character, present in the young of some species of flying fishes and absent in young of others, without any known reason, and a character without any known function, is a single or double barbel, frequently large, or fringed, hanging from the chin. Lacking any other explanation,

selves into two groups, according as the pectorals only are used as planes in flight, or the ventrals also, placed farther back, are enlarged and function as secondary planes. The first group are sometimes spoken of as two-winged, the latter group as four-winged flying fishes, and the two seem to have been derived respectively from primitive forms resembling *Evolantia* and *Fodiator*.

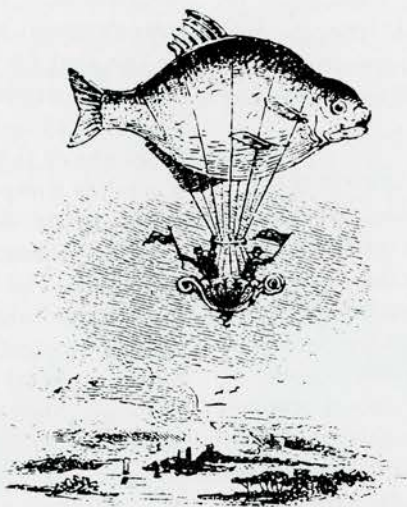
Our study of the flying fishes of the family *Exocoetidae* indicates for them a family tree the main features of which are explained in the diagram on page 73.

This group shows certain progressive modifications of its variant characters very prettily. Certain notable changes, which are somewhat involved, we have attempted to show in the appended diagram. A progressive shortening of the

jaws is shown in the top row of heads (*Strongylura* to *Hemiramphus*, and *Fodiator* to *Cypselurus*). This may represent phylogenetic development along one line of specialization in one character. Then along the bottom row of heads we have indicated the young of these same genera, so that reading vertically one finds the ontogenetic development of each form from youth to old age. Thus with ontogeny and phylogeny as ordinates, various curves may be plotted, delimiting the reduction of either jaw both with reference to phylogeny and ontogeny. Reading from the left to the first curve,

we have the long upper jaw only in the adult form of *Strongylura*. To the right of this line we have all small upper jaws. Reading to the second curve, we have long lower jaws which reach from the young of *Strongylura* to *Hemiramphus* and to the young of *Fodiator*. To the right of this line we have both jaws short. The cross-hatching emphasizes this overlap. One thing that this method of plotting brings out forcibly is that the *Hemiramphi* amount to fixed larval *Strongyluræ*—whereas the long lower jaw of young *Fodiator* is simply the retention of an ancestral character in young stages.

#### THE FLYING-FISH.



Tail piece to the chapter on "The Flying Fish" in Yarrell's *History of British Fishes*, Vol. 1. Possibly engraved by Thomas Bewick